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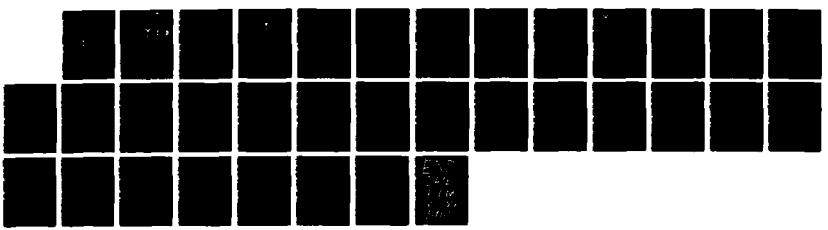

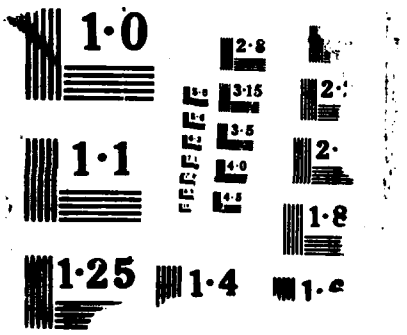
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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

CD ROM: POTENTIAL USES AT AIR UNIVERSITY

MAJOR RUSSELL H. MATTERN 88-1685

"insights into tomorrow"

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AUTHOR(S) MAJOR RUSSELL H. MATTERN, USAF, BSC

FACULTY ADVISOR LT COL JAMES R. MACEY, ACSC/EDN

SPONSOR LT COL JAMES R. MACEY, ACSC/EDN

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Compact Disc Read Only Memory (CD ROM) is an optical data storage medium particularly suited for large data bases. It offers users large volume storage at low cost and can be integrated into present personal computer (PC) systems. This report investigated the feasibility of using CD ROM technology in various missions at Air University including the Air Command and Staff College Resident and Associate Programs. The report concludes CD ROM technology will be most valuable for implementation at the Academic Instructors School and the Air University Library.

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PREFACE

Compact Disc Read Only Memory (CD ROM) is an optical data storage medium particularly suited for large data bases. One disc can store 682 megabytes of data; over 220,000 pages of text. A CD ROM looks identical to its audio Compact Disc (CD) counterpart and utilizes a similar disc drive. This report compares CD ROM technology to the data base requirements of several missions in Air University and concludes CD ROM will be valuable at the Academic Instructor School and the Air University Library.

Thanks and appreciation go to Mr Jerry Boling, Cross Cultural Education Branch, International Officer School; Ms Lowell T. Berenguer, Assistant Systems Librarian, Air University Library; Capt Ronald D. Ford, Chief, Information Systems, Air Command and Staff College Resident Program; Mr John D. Morrow, Evaluation and Computer Application, Academic Instructor School; Lt Col Ken Richardson, Chief, Instructional Systems and Technology Division, Air Command and Staff College Associate Program; and Maj Charles E. Zimmer, Technology Integration, Air War College, all from Air University, Maxwell AFB, Alabama for their sincere support during this project. Additional thanks go to those in industry; Ms Lisa Huber, Customer Representative, On-Line Computer Systems Inc., Germantown, Maryland and Mr Robert Van Eijk, Product/Sales Manager, Laser Magnetic Storage International Company, Colorado Springs, Colorado. The author would like to thank Colonel David Simpson, Associate Chief, Biomedical Sciences Corps (Optometry), USAF for his support in this and other endeavors. To my sponsor and faculty advisor, Lt Col James T. Macey, Chief, Educational Technology Division, Air Command and Staff College Resident Program, I extend my sincere appreciation and thanks, for all the hours of patient assistance and support. And finally, to my friends and colleagues of ACSC Class of 1988, No Ka Oi and Aloha.

ABOUT THE AUTHOR

Major Russell H. Mattern graduated in 1971 from the United States Air Force Academy, Colorado Springs, Colorado, earning a Bachelor of Science degree in Computer Science. He was assigned to Aeronautical Systems Division, Wright-Patterson AFB, Ohio as Lead Software Design Engineer, Air Launched Cruise Missile Program. Major Mattern earned a Master of Science Degree in Computer and Information Science in 1974 from The Ohio State University. Major Mattern earned his Doctor of Optometry Degree from the The Ohio State University College of Optometry in 1980 under the United States Air Force Health Professions Scholarship Program. His assignments include Staff Optometrist, Wright-Patterson AFB, Ohio, 1980 - 1982; Chief, Optometry Services, Osan Air Base, Republic of Korea, 1982 - 1983; and Assistant Chief, Optometry Services, Hickam AFB, Hawaii, 1984 - 1987. He completed Squadron Officer School by correspondence in 1974, Air Command and Staff College by seminar in 1984, and is presently attending Air Command and Staff College in residence at Maxwell AFB, Alabama. Major Mattern is a Fellow of the American Academy of Optometry and an Adjunct Professor of the Pennsylvania College of Optometry, Philadelphia, Pennsylvania. Major Mattern is the first recipient of the Col Floyd M. Morris Award for the United States Air Force Optometrist of the Year, 1986. He was the consultant to the Associate Chief, United States Air Force, Biomedical Science Corps (Optometry), for Information Systems. He will receive a Master of Science Degree in Personnel Counseling from Troy State University, Montgomery, Alabama in June 1988. Major Mattern served on the hospital ship USNS Mercy as Chief, Optometry Clinic, from February to July 1987 on its Humanitarian Mission to the Philippines and the South Pacific.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

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REPORT NUMBER 88-1685

AUTHOR(S) MAJOR RUSSELL J. MATTERN, USAF, BSC

TITLE CD ROM: POTENTIAL USES AT AIR UNIVERSITY

I. **Purpose**: To explore CD ROM technology, its properties and characteristics, and compare them to the data base requirements of missions at the Air University. If appropriate applications for CD ROM are found within Air University, recommendations will be made for its use.

II. **Problem**: Many missions within Air University use large amounts of textual material, among them the Air University Library. Large amounts of textual material and data require massive storage especially if this data is in printed form. Even in the form of microfiche, data can require significant amounts of storage area. Though online systems provide the user with rapid response, user terminals must be tied into a mainframe computer. Access to the database may be limited by the number of input ports. Overhead costs are incurred to maintain the data base in the mainframe. In the case of the Academic Instructor School, there is no mainframe for tie in. Their data base must be limited in size and usable on individual Personal Computers (PCs). The question to be asked here is: does there exist a medium for data storage which provides large capacity, compactness, portability, and does not require a mainframe for direct support?

III. **Data**: Compact Disc Read Only Memory (CD ROM) is an optical data storage medium particularly suited for large data bases. It offers large volume storage at low cost and can be integrated

into present personal computer (PC) systems. One CD ROM has the capacity for 220,000 pages of text, the equivalent of 1,500 floppy discs or 27, 20 MB hard discs. Though mastering a CD is expensive, between $5,000 and $10,000 per disc, replication of additional discs is inexpensive; approximately $7.50 to $10.00 each. A CD ROM is just as portable and durable as its audio CD counterpart. CD ROM drives are available as stand alone units which can be integrated with a PC similar to a stand alone hard disc drive. Additionally, some CD ROM drives fit into a half height slot of a PC.

Several missions at Air University were examined as potential users of this technology. They were: Air War College, Air Command and Staff College Associate and Resident Programs, Academic Instructor School, International Officer School, and Air University Library.

IV. **Conclusions**: The Academic Instructor School and the Air University Library were found to have use for CD ROM technology. Their data base requirements fit the criteria for use of CD ROM. Although other missions at Air University might benefit from the technology also, newer technology allowing user interaction appear more appropriate such as CD-I (Compact Disc Interactive) and DVI (Digital Video Interactive).

V. **Recommendations**: The Air University Library and Academic Instructor School should consider use of CD ROM technology to better enhance attainment of their mission goals. Both can benefit directly by its use and should take steps to acquire the necessary drives and CD ROM discs.

Chapter One

CD ROM TECHNOLOGY

INTRODUCTION

"The giant has awakened. Shouldn't we?" (12:78). Jim Seymour asked that question in his PC Magazine article, "CD--ROMS: Who's Been Sleeping?" CD ROM is the acronym for Compact Disc Read Only Memory. Though the audio version of the CD has been with us for some time, its counterpart, CD-ROM is just now coming into prominence. The volume of digital data storable on a CD ROM is a staggering 550 megabytes, the equivalent of over 150,000 printed pages (2:47). Compared to its magnetic storage counterparts of floppy and hard disc, CD ROM offers the user far more storage capability at low cost. Seymour was alluding to the fact that we knew CD ROM was on the horizon; now that it's here, what are some of the uses for the technology?

The purpose of this paper is to explore CD ROM technology to determine its characteristics, advantages, and disadvantages as a storage medium. Several CD ROM drives and their performance specifications will be reviewed. Portions of the training mission at the Air Command and Staff College and other missions at the Air University may benefit from CD ROM technology. If potential applications are found, recommendations will be made which may include specific systems for implementation.

CD ROM technology presents a new storage medium for personal computer (PC) users. To better appreciate its capabilities and limitations this report discusses its structure and properties, methods used for error detection and correction, data encoding, and storage capacity. Despite CD ROM's brief history, it has made significant inroads in many fields. Applications in publishing, business, education, library science, medicine, law, weather, cartography, and navigation will be discussed. Finally, Chapter One will conclude with a discussion of CD ROM's advantages and disadvantages.

COMPACT DISC STRUCTURE AND PROPERTIES

Audio CDs and CD ROMs share a common structure. Both are based on a polycarbonate disc having a diameter of 120 mm and a thickness of 1.2 mm (6:20). The diameter of the program area is

50mm--116mm and the track pitch (distance between tracks) is 1.6 microns (3:6). One micron is one thousandth of a millimeter. The 1.6 micron track pitch "corresponds to a track density of 16,000 tracks per inch (tpi), much higher than the figures associated with floppy (up to 96 tpi) or Winchester [hard disc] (several hundred tpi) magnetic discs" (2:58). This high tpi for CD ROMs translates into one continuous track "almost three miles [long]" (2:58). Along this track are pits and lands (2:58). The pits are etched depressions in the surface of the disc; the lands are the flat areas between pits. An estimate of the total number of pits on a CD is 2 billion (2:58).

Audio CDs and CD ROMs use constant linear velocity (CLV). CLV implies the portion of the CD **under the optical reader** never varies speed whether data is being read from the inner or outer tracks of the CD. Thus, the rotational speed of a CD while reading data on the innermost track would be near 530 rpm while the speed of the CD reading data on the outermost track would be closer to the slower, 200 rpm (3:6). Floppy and hard disc media use constant angular velocity (CAV) which is in contrast to CD ROM's CLV. That is, the disc revolves at a constant speed, independent of the track, so that inner sectors are smaller than outer sectors. This implies some space of the storage medium is wasted compared to CD's CLV. CD ROMs use of CLV allows the storage of more data on each disc than if it used CAV. The structure and properties of CD ROM provide a high density medium for data storage.

COMPACT DISC ERROR DETECTION AND CORRECTION

With the tremendous amount of data contained on a CD ROM, one might expect potential problems with reading data. Actually, error rates are extremely low through the use of error detection and correction schemes. The block error rate for audio CD and CD ROM is less than 3 x 10**2 (3:6). A block is 2352 bytes long (3:6). Though this rate is acceptable for audio CD as "a 2340-byte sector represents less than 1/75 of a second of" (2:73) music, a CD ROM user requires error rates of less than 1 x 10**12 (3:6). This is accomplished by various error detection and correction techniques and "corresponds to a single-byte error in roughly every 2000 CD ROM discs" (2:73).

A simple example of an error detection method uses checksums. Suppose five 2-digit numbers are to be placed onto the CD ROM, e.g. 57,34,78,65,21. A sixth 2-digit number could be added which is the sum of these numbers less the hundreds digit, e.g. the sum is 255 and the checksum is 55 (2:74). This method will detect a single digit error, but how is it corrected? Hamming codes can be used for both the detection and correction of data; however, for CD ROM technology, Cross Interleaved Reed-

Solomon Code (CIRC) is mainly employed (2:75-77). Layered ECC (Error Correction Coding) can be "performed by the host computer's software" (2:78) to further enhance error detection and correction. Both CIRC and ECC are not infallible. But given that ECC is expected to fail once in 10,000 (10**4) uses and that ECC is used only after CIRC fails, which is once in every 10**9 bytes, that would imply an error rate of one byte in every 10**13 bytes (2:83). This is an order of magnitude better than "the 'acceptable' error rate of 1 x 10**12" (2:83).

CD ROM DATA ENCODING

Minimum Of 14 Bits To Represent An 8-Bit Byte, Why?

At first glance it would appear that if CD ROMs have pits and lands, then pits are 1's and lands are 0's or vice-versa. Unfortunately, CD technology is not that simple. To better understand how a CD can generate data in 0's and 1's, imagine taking a walk on a shiny circular sidewalk that's revolving. There are steps along this sidewalk, but they are unusual. These steps allow you to step up one level and eventually back down; in other words, there are only two levels to these steps. Suspended over this sidewalk is a spot light facing downward with photodetectors around it. If the spot light is shining on a flat portion of the shiny sidewalk then light is fully reflected upward toward the photodetectors and a stream of signals, channel 0's, are sent (2:65). However, when a step comes along, very little of the light is reflected upward toward the photodetectors causing a channel 1 signal to be sent during the transition upward (2:65). Once the light strikes the flat surface of the upper step, channel 0's are once again sent. What happens when the step down occurs? Since it is a transition, and little light will be reflected upward, a single channel 1 signal is sent, followed by channel 0's (2:65). Channel 1's are only generated by transitions up or down and channel 0's represent the flat areas whether they be valleys (lands) or plateaus (pits) (2:65). See figure 1:

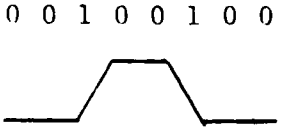

Figure 1
Channel 1's are sent at transitions up or down.

Further, a transition up cannot be followed immediately by a transition down without at least one 0 in between (2:65). By convention for CD ROMs, every channel 1 must be followed by at

least two channel 0's (2:65). Thus, a "1" is represented by 100 on the CD ROM (2:65). This limitation is due to pit size and the wavelength of the gallium arsenide laser used in most CD ROM drives (2:65). The focused beam of the laser is small, as are the pits and lands (2:65). To ensure data is properly resolved by the optical system, a minimum of a 3-bit grouping is needed to represent each 1 of an 8-bit byte (2:65). This explanation implies if a byte contained all 1's, then 24 bits would be required. This is not the case; a method has been developed, called binary channel code, to represent each byte by only 14 channel-bits. The binary channel code employed by CD ROM "is called EFM (Eight to Fourteen Modulation)" (2:65). Since a final 1 in one byte could be confused with a leading 1 in the next byte, 3 merge channelbits are used to separate bytes (2:66). This makes 17 channelbits required to represent one 8-bit byte.

The **frame** is the next larger unit of measure on CD ROM (2:66). "A set of 24 of these 17-bit symbols is combined with a sync pattern. . ., a control and display symbol, and 8 error correction symbols to form a **frame**, which is the basic unit of information storage on a CD" (2:66). Working out the mathematics, twenty-four 8-bit bytes (192 bits total) require 588 bits of representation on the CD (2:67). A sector/**block** on a CD is equal to 98 **frames** (2:67). Seventy-five **blocks** per second can be read on CD giving "a sustained user data rate . . .of 153.6K bytes per second" (2:67). Despite so many bits being required for encoding and "housekeeping chores," CD ROM's storage capacity is quite amazing.

STORAGE CAPACITY

CD ROM offers tremendous storage capability. All CDs have 74 minutes of storage capacity for data but many use only 60 minutes worth of the available space (2:68). The additional 14 minutes of data is derived from "the outer 5 mm of the disc" (2:68). "This just happens to be the hardest area to make well and keep clean" (2:68). Using the full 74 minutes on the CD allows the storage of 682 MB, while 60 minutes equates to 553 MB (2:68). Using a calculator, 553 MB translates to the equivalent of over fifteen hundred 360 KB floppy discs or over 220,000 pages of data. If application software is included on the disc, it will reduce space available for data by an equivalent amount of bytes. Given the tremendous storage capacity of CD ROM, what are some of its present applications?

CD ROM APPLICATIONS

CD ROM technology is having substantial impact in the following disciplines: publishing, business, education, library science, medicine, law, weather and cartography. This portion of

the report will examine the use of CD ROM technology in each. This technology is useful for application in any discipline requiring storage of large quantities of data.

Publishing

The US Navy has used desktop publishing for several years to speed the process of supplying documentation to user commands. They concluded, "Information can no longer be mass produced and stored like line items of supply . . .users no longer have the luxury of waiting days or weeks to receive documentation from some remote repository" (8:24). Their latest plan is to use CD ROM to store technical documentation and other administrative data and integrate it with Zenith 248 computer systems already deployed in the field (8:25). An IBM-PC AT compatible CD ROM drive is about $500-$1000 per copy (8:25). They estimate, "Pages of data can be provided to the end-user at a cost of less than one hundredth of a cent per ASCII page . . ." (8:25). At $10 per disc, CD ROM offers the Navy inexpensive, virtually tamperproof, mass storage for its user commands (8:25).

Business

Business promises to become a large user of CD ROM. CD ROM will offer small business access to data heretofore affordable only in the domain of big business (10:28):

> One application that demonstrates the latent power of CD-ROM is selective information referencing, an area of special concern to small businesses. To make sound decisions, businesses need as much relevant background information as possible. Depending on its size, a company might use everything from clipping services to market-research studies to private research departments to gather information. Though computerized information services are on the rise, high cost has usually restricted their use to large businesses. A less expensive means of information distribution is required for the majority (over 57 percent) of U.S. businesses that employ fewer than 10 people. CD-ROM appears to be the answer to this need (10:28).

Datext of Woburn, Massachusetts produces a Corporate Information Database (10:29). Datext along "with Corporate Technology Information Services Inc. of Wellesley, MA . . .[will] produce CorpTech data base on CD-ROM" (10:29). CorpTech will be a data base of some "12,000 domestic high-technology companies and will appeal to market researchers and financial analysts" (10:29). This will allow small businesses to compete more easily with large businesses in the data and market research areas.

Education

Education is a large user of new technology. Educators are always searching for more innovative methods to bring knowledge to their students. Apple Corporation recognized this fact and helped place many personal computers in secondary classrooms. CD ROM has the opportunity to further the gains made by exposing students to the PC through lessons programmed on the CD. Education Systems Corporation (ESC) "has CD-ROM versions of its reading, writing and math curricula for Grades 1 through 8" on one disc, some 1500 lessons (13:48). The CD ROM version "can support eight to 16 student microcomputer stations. . . ." (13:48). With a CD ROM unit costing approximately $1500, this would be about 1/10 the cost of a hard disc unit to perform the same task (13:48).

Grolier's Electronic Encyclopedia places a 20-volume encyclopedia on CD-ROM. Sixty MB of data stores the encyclopedia text while 50 MB stores the software and indexing system. The indexing system "pinpoints every occurrence of every word in the encyclopedia" (25:--). One CD replaces 10,000 pages, nearly 30,000 entries, over 9 million words (25:--). This CD is in use at the International Officer School, Maxwell AFB, Alabama under the office headed by Dr Jerry A. Boling. This system's response time was faster than I expected. The layout of the index allowed rapid access to articles based on key words. The time from key word "hits" to full text on a particular article was less than one second.

Education, especially areas relying on reference data or Computer Assisted Instruction (CAI), will benefit from CD ROM technology.

Library Science

Libraries are in the information business. CD ROM products can assist library scientists in two areas: "As support tools for library automation activities, including traditional book cataloging and public access catalogs . . .and inexpensive 24-hour availability of databases . . ." (2:509). The slow access time and non-writability of CD ROM technology may be considered undesirable in some fields, but in the library arena they are not a significant limitation and, in fact, can be quite beneficial:

> The often-cited limitations of CD ROM technology--such as the fact that it is not a writable or erasable medium and that it has a slower access speed--do not loom as significant problems in the library environment. Indeed, being able to obtain relatively timely data at a reasonable cost, to store volumes and volumes of this data in a small space, and to offer

local access to highly specialized data never before available, all combine to make CD ROM unusually attractive to libraries (2:509).

Certain advantages spring from the use of CD ROM in the library. In contrast, online systems require charges for connect and cpu processing time. Multiple accesses further increase costs. The number of users accessing an online data base may be limited by lack of input ports. CD ROM becomes less expensive with each additional access, and extensive searches may require less librarian intervention to obtain desired data (2:510). CD ROM may be used to backup certain indexes that are too costly to obtain in duplicate (2:510). It may also backup online systems (16:--). CD ROM also helps save space as many texts can be placed on one CD (2:511).

BiblioFile produced by Library Corporation of Bethesda, Maryland, "consists of two CD ROMs that contain over 1.4 million MARC (Machine Readable Cataloging) records developed by the Library of Congress. This represents all English-language cataloging since 1964 . . .and frequently requested titles published since 1900" (2:513). A price tag of $2930 includes a CD ROM drive and interface which can be used with the IBM PC or compatible (2:513).

A host of companies have surfaced in the public catalog access category. Two examples are Auto-Graphics Impact and Marcive's PAC. These companies use CD ROM technology with monthly updates on magnetic media to give customers timely cataloged information. The Bowker Company CD provides access to more than 770,000 in-print and forthcoming books, 25,000 book reviews, 135,000 regularly and irregularly published serials and 300,000 out-of-print books. This CD catalog is called Bowker's PLUS system (17:971).

Libraries will likely become one of the largest users of CD ROM technology and should be looked to as leaders in its use.

Medicine

CD ROM has made its way into the medical community. Microdex Computerized Clinical Information System (CCIS) "consists of four data bases frequently used in hospital emergency rooms for the identification and treatment of abuses of toxic substances and prescription drugs . . ." (4:32). This data base will allow even small hospital emergency rooms to access authoritative medical treatment protocols in a timely fashion, especially in the case of toxic substances. In the case of large medical data bases, the National Library of Medicine (NLM) has several ongoing programs. MEDLINE is the NLM's premier data base albeit somewhat difficult to use. "The first MEDLINE product to appear on CD ROM was from Cambridge Scientific Abstracts, which bundled a year's

subscriptions with its own Life Sciences abstract series" (4:32). Other medical data bases are in CD ROM version or are being translated into that media.

Law

Law offices bring with them the image of a foreboding wall bookshelf stuffed with volumes of court decisions. A significant portion of a lawyer's practice centers on researching historical legal data to discover precedent setting cases. Since this data do not change, the CD ROM becomes an excellent medium for storage. Mike Befeler points out that lawyers have had online systems such as LEXIS and Westlaw for some time but few older lawyers use them (2:545). Befeler offers two reasons for this: 1) older lawyers may be afraid to use the computer, and 2) online connect and usage charges are additive (2:545). His analogy is, "The taxi meter is always running" (2:545). The newer graduates in law have been trained to use online data bases so fear of the computer is not really an issue. The online connect charges **are** an issue however. With CD ROM there are no connect charges except for the initial acquisition of the data base. The user can then sift through the data base at his/her own rate as multiple accesses do not cost more. This is one of the major advantages for CD ROM. A lawyer felt far less anxiety using a CD ROM system compared to an online system (2:548). To handle updates to the legal data base two methods could be employed. One would involve use of some form of magnetic storage device such as a floppy to update a CD ROM (2:549). The other method could be a subscription to a CD ROM data base which is updated each month with a newly produced CD ROM. Possible uses for CD ROM in law are for tax laws, statutes, case histories, legal forms, and patent/trademark searches (2:546). One current use of CD ROM is in Texas where Quantum Access has placed the Texas Education Code and other laws and statutes of interest on one CD for use by administrators (24:4).

The opportunity for use of CD ROM in law is tremendous. The volume of historical legal data is large, and access to it in a timely fashion is important to the legal community. CD ROM implemented on a PC may soon replace the lawyers entire wall of books.

Weather, Cartography And Navigation

Weather and cartography both require large amounts of data. "The National Oceanic and Atmospheric Administration [NOAA] downloads several gigabytes of data every day" (5:35). Armstrong indicates that some of this data has been stored on CD ROM as a reference for future applications (5:35). The possibility may exist that current weather patterns might be related to older ones thus making prediction easier and more accurate.

CD ROM used in map making can be invaluable to both the military and civilian communities. Armstrong indicates that for military applications maps onboard aircraft (5:34) linked with a satellite navigation system can help direct the pilot to a target. Industry can use CD ROM to examine and evaluate data generated by NOAA's Landsat system (5:35). Lumber companies can benefit by examining trends in growth of forests, and petroleum companies can conduct new oil exploration (5:34).

CD ROM offers the tools to make weather prediction easier and more accurate. Its contributions in cartography linked with navigation promises to offer pilots more latitude in carrying out strike missions.

Summary Of Applications

Applications of CD ROM span many fields; from business and law to education and medicine. If your child inadvertently swallows a toxic chemical, the physician in the emergency room can use a PC with CD ROM to look up the antidote (4:32). Fighter pilots of the future may reach the target with CD ROM generated maps (5:35). The applications of CD ROM are only limited by the imagination. Any task requiring an extensive data base may benefit from CD ROM technology. Search software and user friendliness may be one of the ultimate factors in the success of this technology. Though the data in any discipline is a major concern, getting to it efficiently and effectively is just as important. Knowing the advantages and disadvantages of CD ROM will help the potential user decide if it is the correct technology for his/her application.

ADVANTAGES AND DISADVANTAGES OF CD ROM

Advantages

1. **Storage Capability.** CD ROM's massive storage capability is its overwhelming forte. With the capacity to store over 220,000 pages of text, the equivalent of 1,500 floppies, or 27 Winchester 20 MB hard drives, CD ROM offers the user tremendous capability at low cost.

2. **Increased access to information.** CD ROM makes data bases portable. Online connection to mainframe stored data bases is not required. The number of users is limited only by the number of CDs distributed. Researchers will no longer spend countless hours at the library looking up articles or bibliographic data. They can browse at home with their own PC if they possess a CD ROM drive. Online connect and usage charges will be eliminated.

3. **Unalterable and virtually indestructable storage medium.** CD ROM offers superb protection and extremely reliable storage of

data. The plastic coating of the CD protects the data below, and should the CD become scratched, its data can usually be read due to the method of focusing of the laser beam (2:61) and the error detection scheme. CD ROMs are not alterable; only specially designed CDs called Write Once Read Many (WORM) are alterable (3:109). Head crashes are virtually nonexistent as the distance between head and medium is 2000 times that of the Winchester hard drive (2:61).

4. **Small storage space required.** Compared to the printed page/book, CD ROM offers tremendous space savings. This would be particularly important in areas where space for storage of large volumes of data is at a premium. Small libraries could benefit immediately from CD ROM technology. Though it is obvious that CD ROM provides better space management than books, it also provides better storage than microfiche (1:128). Text is easier to read on a monitor employed with a PC/CD ROM system compared to microfiche viewers. Information on CD can be directly down loaded to a printer in contrast to microfiche (1:132).

5. **CD ROM can be multi-media.** CD ROMs can store text, data, and images (at a cost of approximately 500 KB per still frame (22:--)). Audio data (a digital to analog converter similar to the type found in audio CD players would have to be built into the CD ROM player) can also be added to a CD ROM (1:132).

Disadvantages

1. **Data on CDs cannot be changed.** Once a CD is produced, the information cannot be altered. In the case of historical or retrospective data bases, this is a plus. In the case of an application requiring frequent updating, it is a curse. Applications of CD ROM must be chosen carefully. Information which never changes, such as previous law decisions, is quite appropriate for CD ROM. Some portions of library data bases are also quite suitable. However, if an application requires monthly updating, such as periodical indices, a CD ROM system could be married with a hard drive capability. Here the main data base could be stored on the CD and monthly updates could be added to the hard drive. Some CD ROM data bases do offer monthly updates (14:48).

2. **CD mastering is expensive.** Several steps are required to master a CD ROM once the prospective data base has been targeted. These steps are data capture, database creation, data preparation, pre-mastering, mastering, and replication (1:47-53). Data capture is the acquisition of data in suitable form for software manipulation (1:48). For example, if several books are to be placed on a CD ROM, they must be in a form the vendor can use such as ASCII code (1:48). The user can save money and time if he/she supplies the text is this form; if not, the vender will accomplish it and add it to the charges.

Database creation makes the captured data more accessable by organizing it and establishing the search and retrieval schemes (1:49). Data preparation is one of the most important areas; it "build[s] the directory that will be used to locate the data on the CD ROM disc and . . .build[s] physically the image of the CD ROM database on magnetic tape" (1:51). Directory structure is important; a good directory allows faster access times. Access times for CD ROM systems are very slow compared to hard drives. The Grolier Electronic Encyclopedia stores 60 MB of data but uses 50 MB to store related overhead software and indexing system. This allows the Grolier CD to give quick response times at the expense of space on the CD. "Pre-mastering comprises taking the database in 2 Kbyte blocks and adding the 12 bytes of synchronisation [sic] data, 4 bytes of header data and the 288 bytes of additional error detection and correction coding that are specified . . ." (1:53). Finally mastering takes place which "is the actual creation of the CD ROM master disc" (1:53). Replication is the stamping out of disc copies like its audio counterpart (1:53). The cost for all these steps varies; one recent quote from Reteaco Inc. is $9,995 for 400 MB of text (9:25). 3M Company will master a disc from "between $4,000 to $8,000 depending upon the time frame" (3:9). Once the CD is mastered, replication can be accomplished at prices nearing those of audio CD's, "$7.50 per replica disc in quantities of 1,000 to 4,999 . . ." (3:9).

3. **Special CD ROM play back equipment is required.** CD ROM drives use the same technology as audio CD players except they do not require the digital to analog converter used in audio CD players. CD ROM players can be incorporated into a PC or used as an external peripheral (1:61). Commercial users presently buy most of the CD ROM drives. When the consumer joins the market, drops in price from the current $800 to $1000 level should be realized (20:--).

4. **Access times for CD ROM are slow compared to hard disc.** Access time is often misused; it really consists of several different times including radial positioning time (also called radial access time), settling time, open loop time, and latency (2:50). "Typical average radial access times are 500 ms or more [for CD ROM], compared with 70 for cheap Winchesters and 40 or less for better Winchesters" (2:51). Latency is problematic for CD ROM drives, "running between 60 and 150 ms average, compared with 8 for typical Winchesters" (2:51). Data transfer rates for CD ROM drives run between that for floppies (250 Kbit/sec) and Winchesters (5 Mbit/sec) at a rate of 1.3 Mbit/sec (2:51). Since CD ROM uses CLV, transfer rates for all drives are basically identical across the board as we shall see in Chapter Two.

5. **CD ROM formats are not standardized.** In video, there is the dilemma of two different formats, VHS and Beta. CD ROM is similar in that respect. Sony and Phillips jointly published

the Yellow Book, a reference for CD ROM's **physical** format used by default by many CD ROM producers. It did not, however, fully specify all fields and logical organization (11:18; 1:46). Several vendors collaborated to specify CD ROM organization at the **logic level**; they are called the High Sierra group (1:46). The vendors realize it is in their best interest to standardize CD ROM format so CDs will be interchangeable from unit to unit. Currently, "all CD ROMs can **physically** be read by all CD ROM drives" (1:46).

SUMMARY OF CHAPTER ONE

CD ROM technology offers users outstanding data storage capability at low cost. Its advantages are quite suitable for some applications such as library science and law, while for others it is not. CD ROM technology is meant to complement other data storage mediums, not replace them. Perhaps this is why it fits so well with PCs and their magnetic storage devices, floppies and hard discs. A user who needs a large capacity storage medium that is unalterable, virtually indestructable and requires no updating should consider CD ROM. Knowledge of what CD ROM drives are available and their performance specifications can assist the potential user in choosing the correct system for his/her needs; this is the subject of Chapter Two.

Chapter Two

CD ROM DRIVES

INTRODUCTION

Many CD ROM drives are appearing on the market as the technology is discovered by industry and the consumer. Several manufacturers' CD ROM drives will be considered. The basis for comparison will be their equipment features and performance specifications. The major manufacturers of CD ROM drives are Philips, Hitachi, and Sony. Manufacturers with less of the CD ROM drive market are Denon, Toshiba, Panasonic, Sanyo, and JVC (1:64-65). This chapter will limit itself to the offerings from Philips, Hitachi, and Sony, as they provide a representative cross-section in specifications, cost, and performance.

PHILIPS

Philips offers four drives: the CM 100 ($1040), the CM 110 ($1470), the CM 201 ($715), and the CM 210 ($1055) (26:--). Control Data Corporation joined Philips to produce drives with the Philip's logo under a company named Laser Magnetic Storage International Company. "The CM 100 is a desktop unit with serial interface. It interfaces with the IBM PC/XT/AT and true compatibles through a half height controller card, the CM 153. The CM 100 drive is also available with a SCSI interface: the CM 110" (21:--). SCSI stands for Small Computer System Interface and "is becoming the preferred CD ROM--minicomputer connection" (3:144). Both the CM 100 and CM 110 share a throughput of 153,600 user bytes/sec, CLV of 1.3 m/sec, head positioning time of less than 1 msec track-to-track, and average positioning time of 1 sec with a maximum of 2 sec. The 200 series drives are both half height for use inside a PC. The CM 210 has the same SCSI as the CM 110. Both offer access times of less than 1 sec maximum. Transfer rates are the same as the 100 series except in mode 2 where rates can reach 175.2 Kbytes/sec. All Philips drives can handle a CD ROM with 600 MB of information (21:--). "The Philips CM 100 drive has been in production since July 1985 . . .Over ten thousand units have been shipped to customers" (21:--).

HITACHI

Hitachi makes four units: the CDR-1503S ($884), the CDR-2500/2500S, and the CDR-3500. The CDR-1503S is a desk top model. Its transfer rate is identical to the Philips 100 series, 153 Kbytes/sec. Access time average is listed as .8 sec with average latency inner track of 70 ms and 150 ms outer track. Capacity is 552 MB. The CDR-2500 and CDR-2500S share the same performance specifications with the CDR-1503S except that maximum access time is faster, 1.0 sec with average access time of 0.5 sec. The CDR-2500 is designed as a full height, built-in peripheral for a PC, while the CDR-2500S is a stand alone unit with built-in power supply. The CD-IF25A interface card must be used to connect the units to IBM PC and XT. The CD-IF25A-2 interface card is needed if the unit is being connected to the IBM AT. The CDR-3500 shares the same specifications as the CDR-1503S but is packaged in a half-height format which allows it to replace a half-height floppy. It includes audio circuitry and uses the same voltages as a floppy. The CD is held in a cartridge that helps prevent fingerprints and allows for vertical installation (19:--).

SONY

Sony produces three units: the CDU-100, CDU-200B, and the CDU-5002. On-Line Corporation quotes the CDU-100 and CDU-200B at $915 each (20:--). Linda W. Helgerson, in her article, "A Buyer's Guide to CD-ROM Drives" places the cost of the CDU-5002 at $425 (7:60). The CDU-100 and CDU-200 are both front loading, stand alone units, with their own power supplies. The CDU-100 can be "daisy-chained with up to four more CDU's" (1:64). Daisy-chaining allows the user to access data on any of the four CDUs. The CDU-200 has a SASI/SCSI interface (1:64). Storage capacity for all the Sony drives is 540 MB (3:52). The CDU-5002 is designed to fit into a PC and uses the SASI/SCSI interface (1:64). No specifications for access time for the Sony units were found. Data transfer rates would likely be the standard for CD-ROMs since CLV is used, 153 Kbytes/sec.

SUMMARY OF CHAPTER TWO

All the units discussed above boast hard read error rates of 1 X 10**12 or better. By design, all drives use CLV which makes all data rates equal unless information bits can be better packaged on the CD. As to which unit to use in a particular application, the factors to consider would be: stand alone vs internal, interface design such as SCSI, cost, reliability, maintainability, capacity, access times, and service. Cost is a very time sensitive issue. As more CD ROM drives are produced, costs become lower. Quantity purchases further reduce per unit

cost. Information as to reliability of the products under actual usage was lacking but Hitachi claims an MTBF (Mean Time Between Failure) of 10,000 hours (19:--).

In choosing a CD ROM drive, the user must be certain it meets his/her requirements. The performance of all units is nearly equal. More important issues might be, do I need a stand alone unit, or because desk top space is limited, one that is incorporated into the PC? Will the access times and data rates meet my minimum requirements? Do I need the daisy-chaining capability of the Sony units? Answers to these questions and those above will allow the user to select the unit(s) best meeting his/her needs.

Chapter Three

POSSIBLE AREAS FOR CD ROM APPLICATIONS, ANALYSIS, RECOMMENDATIONS

INTRODUCTION

Six areas of possible usage for CD ROM technology at Air University, Maxwell AFB, Alabama were investigated. They were the Air Command and Staff College Associate Program, the Air War College, the Air Command and Staff College Resident Program, the Academic Instructor School, the International Officer School, and the Air University Library. Each organization's mission requirements in the data base area were analyzed and related to existing CD ROM technology. In any area where mission requirements overlapped with the technology, suggestions for possible usage either now or in the future were made.

AIR COMMAND AND STAFF COLLEGE ASSOCIATE PROGRAM

Lt Col Ken Richardson, Chief, Instructional Systems and Technology Division, Air Command and Staff College Associate Program indicated that the ACSC Associate Program is responsible for develop the curriculum, study materials and testing for those enrolled in its program. He stated the program could expect up to 3,000 new enrollees each year. Each student receives a large box of lesson material which stacks some three feet high. An estimate of 30 pages per lesson and 52 lessons brings the number of text pages to 1,560. Adding administrative documentation to this yields nearly 2,000 pages of text. Lessons 14, 27, and 40 had wargaming associated with them requiring use of floppys and a PC. Alternating lessons are supplied with a video tape to supplement the seminar (23:--).

At 2,000 pages of text, the Associate Program for ACSC would use only a small portion of the storage on a CD ROM with capacity between 150,000 and 220,000 pages. Adding the computer war gaming software to the CD ROM would still leave much storage available. Introducing still frame images at 500 Kbytes each would allow for an estimated 1,000 pictures/diagrams/maps over and above the storage required for the text and war games. The major drawback is the text material being read on a display terminal. Anyone who has done this for long periods of time realizes it is fatiguing. As an optometrist, I have examined a

significant number of patients with vision complaints related to video display terminals. Even if lessons were short in nature to preclude fatigue, use of CD ROM still presupposes student access to a CD ROM drive and PC. That issue would have to be resolved by the Associate Program and the related base education offices.

Perhaps an area more applicable to the Associate Program would be in writing assignments. For instance, if an assignment were given to write about a famous military leader, access to the materials on the Project Warrior bookshelf at Air University Library would be advantageous. Add to that material from periodicals on these leaders and the student would have a wealth of material from which to compose his paper. The vast quantity of material held on a CD ROM would be beneficial for this type of assignment.

In conclusion, the ACSC Associate Program would not benefit from placing all its printed material on CD ROM for use by students due to the lack of drives to read it and the efficacy of reading all lesson material off a video display terminal. However, a future application may involve the placement of data base material, e.g. about famous warriors, on CD ROM to support student research and writing assignments.

AIR WAR COLLEGE

Maj Charles E. Zimmer, Chief, Technical Integration at the AWC, indicated if CD ROM technology is used at all at AWC, it would be in the distant future for Computer Assisted Instruction (CAI) for training at the knowledge level. It may be used at the application and synthesis level in simulations only, but this is doubtful. He has used Microsoft's Bookshelf and finds it very convenient. Microsoft's Bookshelf consists of The Chicago Manual of Style, American Heritage Dictionary, Daniell's Business Information Sources, Roget's II Thesaurus, Bartlett's Familiar Quotations, and the US Postal Service National Five-Digit & Post Office Directory. Maj Zimmer sees more potential for the use of interactive laserdisc, not CD ROM, at the AWC for updating student data, training data, weight control and international officer information. This would allow all data to be contained in one database. It would further allow updates, something CD ROM cannot offer (27:--).

My conclusion is that CD ROM will be a passing curiosity for the Air War College, as more advanced optical storage media such as laserdisc, which allows interaction, would be more appropriate for their data base requirements.

AIR COMMAND AND STAFF COLLEGE RESIDENT PROGRAM

Capt Ron Ford, Chief, Information Systems at ACSC saw no immediate need for CD ROM technology at ACSC; however, he did indicate some areas of future application. Among these would be war gaming, evaluation of leadership styles, reference materials, and indices to references. ACSC presently uses IBM compatible PCs with Bernoulli hard drive cartridges. As he pointed out, this has been more than adequate for student needs in the computing area (18:--).

CD ROM may be used in war gaming but would require down loading to a hard drive to make it interactive. Used for reference materials, CD ROM could provide students and faculty alike with access to many volumes of text used for research. Putting all ACSC research projects on one CD with good indexing would be beneficial to student researchers, allowing them to easily reference previous reports.

ACADEMIC INSTRUCTOR SCHOOL

The Academic Instructor School (AIS) has the role of training instructors to support a vast array of USAF teaching missions. Mr John Morrow, Chief, Evaluation and Computer Applications for AIS, indicated nearly $100,000 of Pioneer laserdisc players have been ordered by AIS to assist in CAI. They are to be installed in early 1988. In all, 11 stations will be built for CAI. The Pioneer player purchased is quite versatile; it can play the 12 inch laserdisc, 8 inch laserdisc and CD ROM. Laserdisc allows full motion, CD ROM stills only. Possible uses for CD ROM may include informal lecture, methodology and communications skills. Mr Morrow sees teaching and instruction moving toward a digital-video thrust in the future. CD ROM may play a large role in areas where stills can be accompanied by text and audio. AIS has been tasked to provide the historical material for both a laserdisc and CD ROM to be mastered at the USAF mastering facility at Hill AFB, UT. Inputs will be drawn from the Center for Professional Development (CPD) and the Air Command and Staff College Resident Program, both located at Maxwell Air Force Base, Alabama (22:--).

The Academic Instructor School will play a significant role in usage of optical storage media. CD ROM and other optical media will play a vital role in the training of instructors to meet Air Force missions. Since CD ROM technology is currently planned for use at AIS, those interested in it could use Mr Morrow as an excellent resource.

INTERNATIONAL OFFICER SCHOOL

The English as a Second Language (ESL) lab at the International Officer School (IOS) has the task of training international officers in English before they commence their studies at the Air War College and the Air Command and Staff College (15:--).

Dr Jerry Boling, Chief, Cross Cultural Education Branch, has a CD ROM drive with Groliers Electronic Encyclopedia tied into a PC. Access and response time of this work station is quite good, usually less than one second for text retrieval. Though this station can be used by international officers, Dr. Boling sees CD ROM as more of a stepping stone to CD-I (Compact Disc Interactive) and DVI (Digital Video Interactive). CD-I is expected out in force this year with limited motion. DVI may steal the whole show with up to 72 minutes of full video on a CD (15:--).

CD ROM for IOS will have limited use. I do not foresee it becoming a vital portion of the ESL program. The ESL lab will better meet its goals with interactive optical storage media such as DVI, laser disc, and perhaps CD-I.

AIR UNIVERSITY LIBRARY

The automated systems portion of the Air University Library (AUL) is tasked to provide the means, using the library's public and technical services, to make information available to meet the needs of the library's users (16:--).

Ms Lowell Berenguer, Assistant Systems Librarian, sees special use for CD ROM technology at AUL. One would be for back up for the current online system. In fact, the current online system could be replaced by CD ROM; however, with the many daily updates to the system, this would be ineffective. Another area for CD ROM use is the periodical indices. Placing the last three year's titles on CD ROM would save space, increase access to the data, and produce more productive researching with improved indexing, and search by key words. ERIC and Index Medicus are now being put on CD ROM. Presently, all access to the catalog data base is limited to the number of online terminals; with CD ROM one drive can support up to 8 stations, and thus the number of terminals is limited only by the number of drives and CDs. Use of the CD could make the entire AUL data base portable. Students could conduct research at home at their leisure without connecting to the main AUL data base. Though it may be tempting to visualize complete digitization of the AUL resources on CD, in fact this would be quite unwieldy. It is more efficient to digitize indices, key words, and where the textual information may be found rather than the text itself. There are exceptions

such as Grolier's Electronic Encyclopedia and other fixed references (16:--).

A substantial number of modules and systems are set for installation at AUL this year. Among them are an acquisitions module for ordering and budgeting, an automated circulation system, and a serials control subsystem of the acquisitions module for ordering and logging in each periodical received. Additionally, an authority control system will set up a standardized name and subject for references coming off the Online Computer Library Center (OCLC). The authority control system will allow a person researching the Vietnam War to find that most information is actually stored under Vietnam Conflict. All these modules and subsystems could be stored on CD ROM as a backup should the main system go down (16:--).

AUL should consider CD ROM as a backup for the systems above as well as the periodical indices. Further, it may be possible to incorporate CD ROM technology in the automated circulation system. Any of the CD ROM drives reviewed in this paper could meet the AUL requirements. A stand alone CD ROM may be more appropriate to allow AUL to integrate it with any of their IBM compatibles. Later PCs can be purchased with the CD ROM drive already integrated.

Recommendations

CD ROM is a viable read only optical storage medium and good complement to magnetic storage media. It has several potential uses in missions at the Air University, Maxwell AFB, Alabama. The best areas for usage are the Academic Instructors School and the Air University Library. Other missions considered by this report would not be good candidates for CD ROM technology as it does not meet their mission requirements. Technologies such as DVI, laserdisc, and CD-I might better meet their requirements.

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